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Individual Study, Pretesting, and Serial Mastery as Strategies In Teaching School Concepts

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Three strategies frequently employed in individualized instruction were tested in a three-way repeated measures design that involved eight computer exercises over a period of six weeks. Exercises compared individual with paired study, pretests with no pretests, and serial with parallel mastery. Posttests revealed an advantage for individual study and parallel mastery, while pretesting had no lasting effect. Questionnaire preferences for paired study and serial mastery suggest that retention improved under conditions of increased cognitive strain. A mechanism involving working memory is proposed and implications for both individualized and grouped instruction are discussed.

Individual Study, Pretesting, and Serial Mastery as Strategies in Teaching School Concepts

Common assumptions in individualized mastery learning programs support three strategies for teaching concepts: self-pacing, pretesting, and serial mastery. Self-pacing permits the learner to concentrate on reaching mastery rather than on keeping up with the class (Bloom, 1968) and is consistent with individual differences (Glaser, 1967; Keller, 1968). Consistent with self-pacing is individual study rather than paired or group study. From the standpoint of operant learning theory, individual study has the additional advantage of demanding more active responding than group study (cf. Holland, 1965).

Pretesting enables the teacher to identify the level of entering behavior and to establish a baseline for evaluating the instructional program. Pretests can therefore aid in adapting instruction to individual differences (Anderson and Faust, 1973). In addition, "test-like events" have been shown to establish performance sets that facilitate learning (Rothkopf, 1966).

Serial mastery requires criterion performance on one objective before work can begin on another. Support for this requirement is drawn from two sources: concept identification experiments, which favor "blocking" of concept instances over interspersing them among instances of other concepts (Kurtz and Hovland, 1956), and task analysis studies, which find that learning improves when prerequisites are mastered before attempting subtasks higher in the learning hierarchy (Gagne, 1962).

None of the strategies, however, rests on firm ground. Self-pacing, which is accompanied by recurrent procrastination, has sometimes compared favorably, sometimes unfavorably with external pacing (Robin, 1974). Similarly, experiments comparing individual study with group study have yielded mixed findings (Anderson, 1961; Klausmeier, Wiersma, and Harris, 1963).

Pretesting is suspect from the standpoint of theorists who advocate minimal errors because a useful pretest has a high error rate and may set up proactive interference.

Serial mastery even in a hierarchical task has not consistently proven superior to non-serial mastery (Merrill, 1965). Because school concepts differ sharply from typical concepts in laboratory studies (Carroll, 1964), parallel mastery involving continuous contrast between concepts may lead to better coding of information than mastering each concept in succession (cf. McMullen, 1973).

The aim of this study was to test each strategy in a school context that nevertheless permitted careful experimental control. Through computer-assisted instruction over a period of weeks in a credit-bearing course, hypotheses were tested that predicted better achievement (1) when students work individually rather than in pairs, (2) when study is preceded by a test, and (3) when concepts are mastered in succession rather than concurrently.

METHOD

Materials

Eight computer exercises dealt with eight sets of concepts in a course entitled "Contemporary Research on Teaching." Distributed before each exercise was a study guide containing one question for each of eight concepts in the reading, e.g. "advance organizer," "prompting," "inspection behavior." The exercise was constructed by means of a concept-cue matrix that assigned to each of the eight concepts a series of cues belonging to four categories: attributes, nonattributes, instances, and non-instances (Figure 1). Four of the eight concepts were assigned

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Insert Figure 1 about here

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to a true-false mode and four to a matching mode. In the true-false mode two cues from each of the four categories were generated for each concept, for a total of 32 cues. In the matching mode, only two attributes and two instances were generated for each concept, since cues for the other three concepts in that mode functioned as nonattributes and noninstances. A total of 48 cues formed the item bank for one exercise.

By means of a batch computer program written in PL-I, the concept-cue matrix was embedded into an interactive program written in Coursewriter II for presentation on scope-and-keyboard terminals linked to an IBM 1500 Instructional System in the Laboratory for Computer-Assisted Instruction at Stony Brook. The interactive program required S to meet criterion on each concept by responding correctly to two cues in succession. Cues were randomly selected without repetition from among those associated with a concept either until criterion was met, eight cues had appeared, or a total of 24 items had been presented in the exercise. The minimum number of items per exercise was 16. Following each response the answer appeared with a feedback comment that elaborated on the answer. A running score was also updated. At the conclusion of the exercise, concepts associated with errors were listed if the exercise was to be retaken.

Half of the concepts in each exercise were randomly selected for testing by paper and pencil on the Course Posttest. For each

of these 32 concepts, a cue was chosen at random from the set of cues associated with the concept. This cue was paraphrased if it was an attribute or recast as a similar situation if it was an example. Half of these 32 items were presented as the Course Pretest.

Following the first attempt at an exercise, the computer randomly selected 12 of the 48 items for the Exercise Posttest, allowing no more than two items per concept. No criterion was required on this test, although the exercise itself was repeated until criterion was reached on all eight concepts.

The eight exercises were organized into two units of four each. After reaching criterion on each exercise in the unit, S took a 24-item Unit Posttest consisting of six cues randomly selected by the computer from each of the four exercise banks, each item testing a different concept. Though only first attempts at Unit Posttests are reported below, S repeated the tests until meeting a criterion of 20 out of 24.

Treatments

Three strategies, each with a contrasting strategy, resulted in six treatment conditions or study modes. Following a counterbalanced 2x2x2 within-S design, the eight exercises were planned so that S studied four of them in each of the six strategies. Randomly divided into four groups, Ss were assigned during Unit I to individual study if they were in Groups A or B, paired study if in Groups C or D, reversing places during Unit II. Two of the four exercises in each unit required serial mastery, two parallel mastery, with Groups A and C encountering different exercises in these conditions than Groups B and D. One exercise in each mastery condition was pretested and one was not pretested. The full design is displayed in Figure 2.

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Insert Figure 2 about here

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Individual study (IS) differed from paired study (PS) only in that S responded without consulting a partner. Partners were encouraged to alternate from session to session as the one who did the typing.

Serial mastery (SM) required either two consecutive correct responses to a randomly selected concept or eight cue-presentations before opportunity was given to move on. In matching mode, since a second concept provided non-attributes and non-instances for the target concept (see Fig. 1), S moved on after meeting criterion on either one. Parallel mastery (PM) proceeded with the same criterion but repeatedly cycled through all true-false concepts and two of the matching concepts. Concepts dropped

from the cycle after criterion was met. The order of concepts on each cycle was random.

Pretesting (PT) occurred at the session prior to the session for which an exercise was assigned. Exercise pretests were identical to exercise posttests (see above), and immediately followed the posttest for the current exercise. If the following exercise was not pretested (NT), S immediately retook the current exercise if necessary.

At the time of the Course Posttest, S completed an evaluation questionnaire containing questions related to the treatment variables (see Table 2). Agreement was measured on a four-point Likert scale.

Subjects

A total of 27 students in a continuing education (graduate) course entitled "Contempoary Research on Teaching" participated during a six-week summer session. Most were elementary teachers and each received credit for the course. However, only 18 completed the experiment as planned. The remainder completed all tasks but because of absences they sometimes worked individually or without a pretest when the design specified otherwise. In such cases, S was given the sample mean for a missing cell in Figure 3 and any cell encountered by S more than once (e.g. IS-SM-NT) was given the mean of S's scores related to that cell.

RESULTS

As displayed in Table 1, performance on material to be pre-

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Insert Table 1 about here

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sented in the six treatment conditions was at the same level on the Course Pretest, although a three-way repeated measures ANOVA did disclose one significant interaction favoring SM with PT concepts and PM with NT concepts ($F=15.7$, $df=1/26$, $p=001$). On the Course Posttest, however, IS gained nearly 30 points and PS only 20 ($F=10.17$), with a similar advantage for PM over SM ($F=10.06$). The interaction, on the other hand, disappeared ($F=1.42$).

A different pattern appeared on the Exercise Posttests, favoring PS over IS ($F=13.23$). None of the other strategies differed, and the interaction disclosed on the Course Pretest was not found ($F=.10$). The interaction reappeared, however, on the Unit Posttests ($F=8.63$, $df=1/26$, $p < .01$), although no other effects were revealed.

While performance was better on concepts studied without a partner, Table 2 indicates that paired study was strongly pre-

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Insert Table 2 about here

- -

ferred over individual study. A strong dislike for pretesting, on the other hand, was not associated with a performance difference between pretested and non-pretested concepts. Verbal comments pointed to the lack of continuous feedback as the major reason for the dislike of pretesting.

In both cases where contrasting strategies significantly differed on the Course Posttest, preference by S ran counter to performance. While scores were higher with PM, the direction of preference was toward SM, just as performance favored IS but preference favored PS.

DISCUSSION

On the three hypotheses tested in the study, only one was confirmed: individual study surpassed paired study. Despite a short-term advantage for working with a partner (Exercise Posttests) and a distinct preference for paired study, the more demanding task of studying alone led to a larger long-term gain.

Though pretesting did not help, neither did it hurt performance, as advocates of errorless learning might maintain. The availability of study guide questions for all concepts may have weakened the mathemagenic effects of pretests (cf. Rothkopf, 1966); in any event, the common practice of monitoring performance through pretests was not brought into question so long as one can tolerate the negative affect that may occur. Perhaps immediate feedback plus more diagnostic and adaptive forms of testing can turn pretesting from a disagreeable to a desirable experience for the student.

Parallel mastery received clear support from the data over a strategy concentrating on one concept at a time. Moving constantly from one concept to another was slightly less preferred, but the additional strain apparently aided later performance. Combined with the data on individual study, this conflict between performance and preference suggests that cognitive stress facilitates school concept learning. A level of stress, however, that either is excessive or is perceived as unwarranted may accomplish nothing, as in the data on pretesting.

A mechanism that may account for the usefulness of cognitive strain involves the role of working memory in handling interruptions (Miller, Galanter, and Pribram, 1960, pp.65ff.) Especially during a parallel mastery task, S must allocate more memory to interrupt handling, i.e. to keeping track of internal plans or

routines that are used to test and construct the various concepts. This enlarged working memory may facilitate rehearsal and coding into long-term memory by providing a staging area in which configurations of cues (i.e. concepts) can be differentiated from one another and "chunked" in a form that later memory operations can regenerate as a whole (McMullen, 1973).

Since both serial mastery and paired study allow S to depend on external memory - the computer's in one case, the partner's in the other - working memory need not be as large as when S must monitor several plans concurrently (parallel mastery) or integrate plans and sub-plans alone (individual study). Data from the Course Posttest support a hierarchy of strategies consistent with demand on working memory: the combination of PM and IS scored highest (.80), SM and PS scored lowest (.58), and both PM-PS and SM-IS scored between with identical proportions correct (.70).

This study has implications for individualized instruction and for forms of grouped instruction as well. It underscores the importance of arranging learning experiences in which individuals must rely on themselves, and it calls for a reexamination, but not rejection, of the common practice of pretesting. Most importantly, perhaps, the study reminds educators that humans are parallel processors, not serial processors only, and that short-range gains of linear sequences may be purchased at the expense of long-range deficits. As an example, recent proposals for "blocking" undergraduate courses, i.e. taking a new course every three weeks instead of five courses the full 15 weeks, should be studied in the light of the relative effectiveness of serial mastery and parallel mastery. While individual differences surely exist, this study cautions against adopting strategies on the basis of immediate gains or preferences rather than performance over time.

FOOTNOTE

1. Each of the four dependent measures (cf. Table 1) was analyzed in the same manner. Results were nearly identical whether all 27 Ss were included or only the 18 who participated as planned (cf. "Subjects" above). If anything, effects were more pronounced with only 18 in the analysis.

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Table 1

Mean Proportion Correct for Items
Presented in Six Study Modes

Treatments		Course Pretest[1]	Exercise Posttests[2]	Unit Posttests[2]	Course Posttest[1]
Individual Study	(IS)	.47	.84	.79	.75**
Paired Study	(PS)	.44	.87*	.81	.64
Pretested	(PT)	.47	.87	.79	.70
Not Pretested	(NT)	.43	.84	.81	.69
Serial Mastery	(SM)	.45	.85	.78	.64
Parallel Mastery	(PM)	.46	.86	.81	.75**
Sample Mean (N=27)		.45	.85	.80	.69

** $p < .01$
1 Paper-and-pencil tests
2 Administered by computer

Table 2

Questionnaire Items and Mean Ratings[a]

1.	I liked working on the exercises myself.	2.41
2.	I liked working on the exercise with another student.	3.18*
3.	I found the pretests on the computer helpful.	1.73***
4.	I preferred working on only one concept at a time.	2.63
5.	I was helped by switching from one concept to another.	2.33

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[a] Four-point scale: 1=strongly disagree, 2=disagree, 3=agree; 4=strongly agree.

* Item 2 minus Item 1: $t=2.65$, $p < .05$.

***Neutral rating (2.5) minus Item 3: $t=4.72$, $p < .001$.

FIGURE CAPTIONS

Fig. 1 Exercise concept-cue matrix, showing cue-banks for four concepts presented in true-false mode and four in matching mode (i.e. all concept names appearing with each cue). Each concept is treated from two angles (subscripts), each focusing on a set of critical attributes (A+) and non-attributes (A-) on which are based, respectively, instances (I+) and non-instances (I-). In matching mode, non-attributes and non-instances are attributes and instances of other concepts. (After McMullen, 1973)

Fig. 2 Strategy variations in the eight exercises for each of the counterbalancing groups.

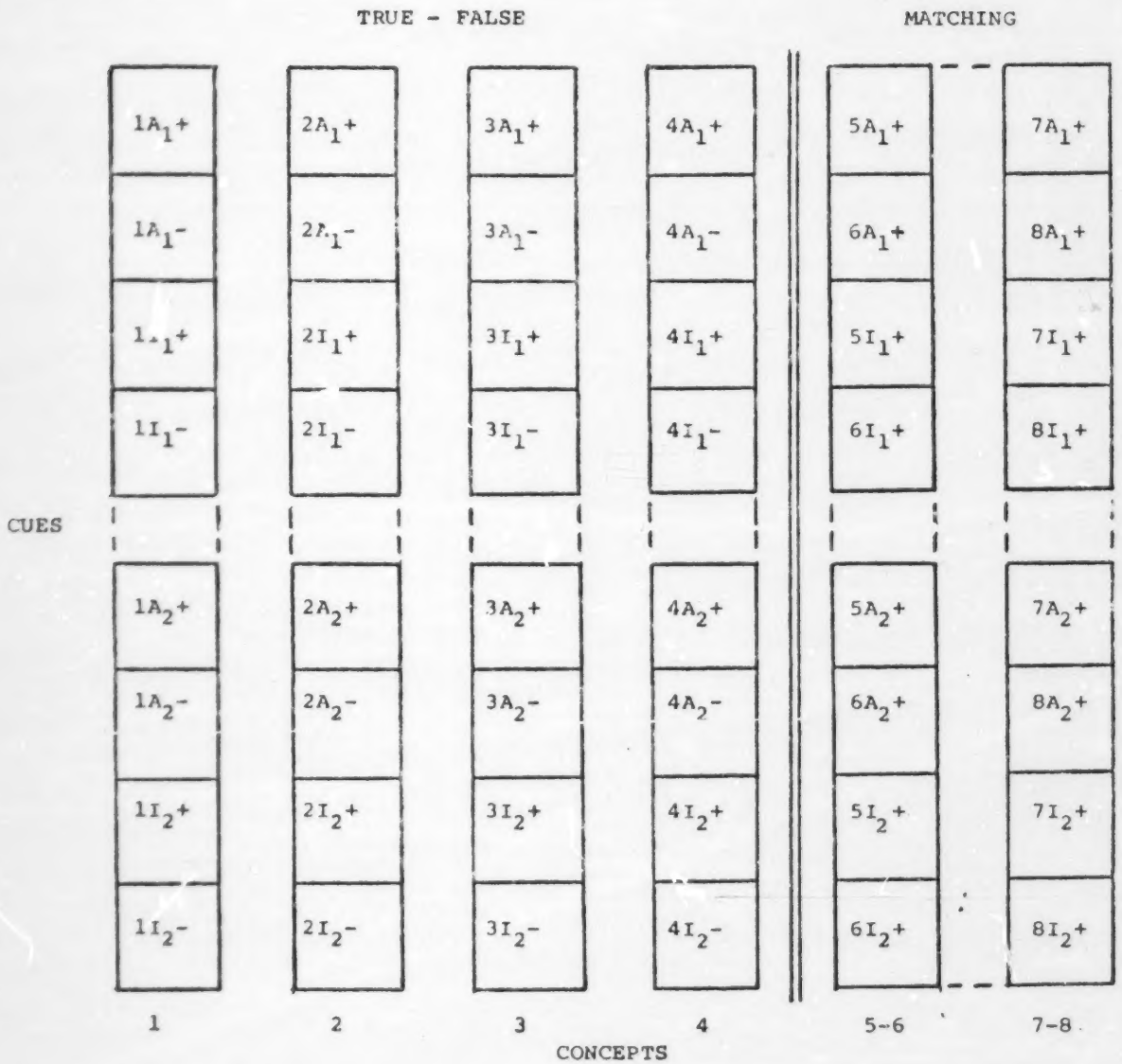
TRUE - FALSE
MATCHING
1A1+
1A1-
1I1+
1I1-
2A1+
2A1-
2I1+
2I1-
3A1+
3A1-
3I1+
3I1-
4A1+
4A1-
4I1+
4I1-
5A1+
6A1+
5I1+
6I1+
7A1+
8A1+
7I1+
8I1+
CUES
1A2+
1A2-
1I2+
1I2-
2A2+
2A2-
2I2+
2I2-
3A2+
3A2-
3I2+
3I2-
4A2+
4A2-
4I2+
4I2-
5A2+
6A2+
5I2+
6I2+
7A2+
8A2+
7I2+
8I2+
1
2
3
4
5-6
7-8
CONCEPTS

Figure 1

GROUPS	1	2	3	4	5	6	7	8
A	IS PM PT	IS SM NT	IS SM PT	IS PM NT	PS SM NT	PS PM PT	PS PM NT	PS SM PT
B	IS SM NT	IS PM PT	IS PM NT	IS SM PT	PS PM PT	PS SM NT	PS SM PT	PS PM NT
C	PS PM PT	PS SM NT	PS SM PT	PS PM NT	IS SM NT	IS PM PT	IS PM NT	IS SM PT
D	PS SM NT	PS PM PT	PS PM NT	PS SM PT	IS PM PT	IS SM NT	IS SM PT	IS PM NT

EXERCISES

IS = Individual Study SM = Serial Mastery
PS = Paired Study PM = Parallel Mastery

PT = Pretested
NT = Not Pretested

Figure 1